INTER CALIBRATION BETWEEN A VIAL SCINTILLATION DETECTOR AND A GEIGER-MUELLER COUNTER

JOE V. MOREY

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by

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PREFACE

Radiation particle counting equipment which may be used at high counting rates in conjunction with Geiger-Mueller or crystal scintillation detectors is employed in this laboratory. It is proposed that this apparatus be used in some instances for estimation of true activities or absolute disintegration rates. The calibrated detector method for this determination was selected since it affords a considerable versatility of the equipment with regard to the sources with which it may be used. A Geiger-Mueller detector with conventionally arranged sample mount and a crystal scintillation detector of the well type were calibrated. Results are given herein together with estimates of reliability.

The writer wishes to thank Professor W. W. Hawes of the Department of Metallurgy and Chemistry for his assistance, encouragement and cooperation in this investigation.

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TABLE OF SYMBOLS AND ABBREVIATIONS

mc	- Millicurie
ml	- Milliliter
E	- Efficiency of G.M.C.
M_o	- Counting rate corrected for background
M	- Observed counting rate of G.M.C.
f_b	- Back scattering factor
f_d	- Dead time factor
f_s	- Self absorption factor
f_w	- Aluminum window and air attenuation
μ/ρ	- Mass absorption coeficient $\frac{mg}{cm^2}^{-1}$
D	- Disintegrations per second
E_s	- Efficiency for V.S.C.
M_s	- Counting rate of V.S.C. after background correction

CHAPTER I

INTRODUCTION

1. Discussion

The determination of absolute disintegration rates has been accomplished by three general methods each of which offers particular advantages. Probably the most accurate of these of wide adaptability is the 4-pi counter in which radiation in all directions from the source is detected with roughly equal efficiency. Sources of moderate area deposited on on-scattering mountings may be counted with efficiency approaching 100%. However, the sample must be introduced inside the detector, a procedure not compatable with rapid or extensive counting requirements. Low geometry arrangements have been proposed for which the efficiency of detections may be calculated. Such arrangements are limited to high activity sources if long time counting is to be avoided. In addition to the time involved, factors such as background corrections and instrument stability become more significant and tend to reduce the reliability of measurements.

Coincidence measurements of beta and gamma radiations emitted nearly simultaneously provide a second method for determination of absolute distingeration rates. Separate counting rates for the two radiations together with the rate of coincident detection may be combined to eliminate individual detection efficiencies. This method requires elaborate instrumentation and also may involve

errors from complex disintegration schemes, possible angular correlations, bremsstrahlung or other sources.

Beta detection efficiency determination by evaluation of counting rates of sources of known strength, probably offers the simplest and most adaptable method for absolute disintegration rates. The main limitations of this method are the accuracy of calibration of standards and the precision to which the half life is known. Beta adsorption by the tube window must be small and the geometric arrangement reproducable, conditions met by the apparatus employed here.

2. Inter Calibrating Procedure

Calibration of the scintillation counter was accomplished by inter comparison of an I^{131} solution. The strength of this solution was determined using efficiences obtained in calibration of the GM counter.

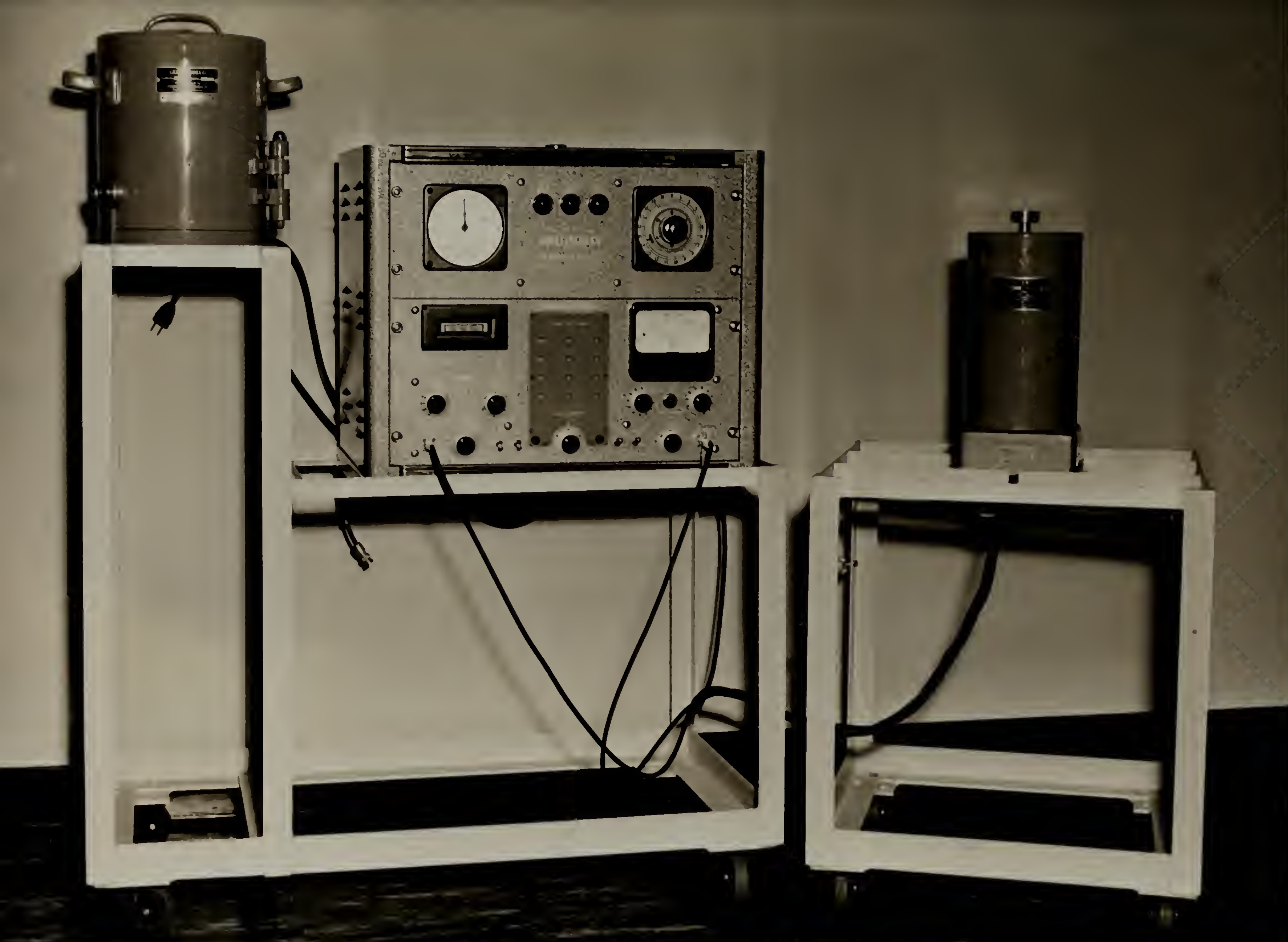


FIGURE 1 - APPARATUS

CHAPTER II

INSTRUMENTATION

1. Apparatus

The apparatus consisted of scintillation counter and Geiger-Mueller counter assemblies together with shields and a scaling unit for use with either assembly. It is shown in the photograph, Fig. 1. A brief description of equipment characteristics and organization, is given below.

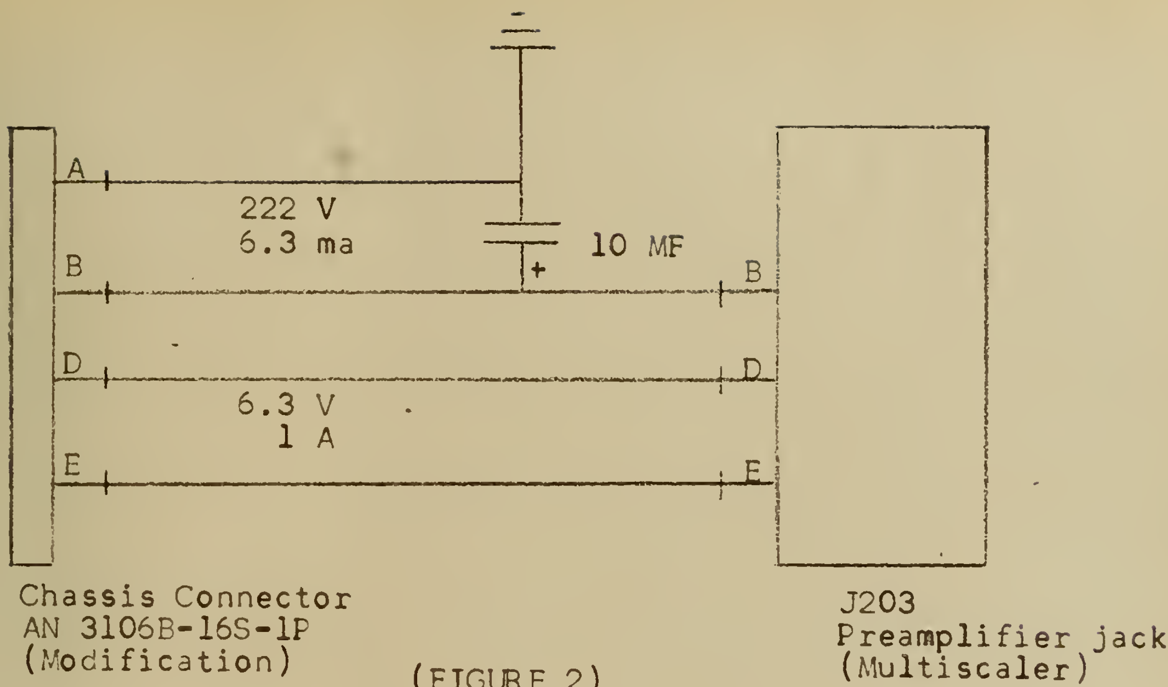
2. Scaling Unit - Model 1070 A

This unit was manufactured by the Atomic Instrument Co. of Cambridge, Massachusetts. It was a binary scaler with a built in power supply, timer, and automatic reset. It could be operated automatically for a preselected number of counts, or for a preselected time or by the conventional manual control.

The main characteristics were as follows: rise time of pulse amplifiers at 10% to 90% of maximum amplitude, 0.3 microsecond; resolving time, 1 microsecond; high voltage continuously variable between 400 to 2500 volts dc; stop clock accuracy, ± 0.02 min; timer accuracy, ± 1 second; and a maximum counting rate of 200,000 cps.

3. Scaler Modification

A minor wiring modification was necessary to permit operation with the scintillation counter. This involved adding a capacity isolated input connector as shown in the diagram, Fig. 2.



(FIGURE 2)

4. Scintillation Counter - Model 2250

This counter was manufactured by the Berkley Division, Beckman Instruments, Inc. of Richmond, California. It employed a thallium activated sodium iodide crystal and an RCA 5819 photomultiplier tube. The crystal was 1½" in diameter by 1" thick, had a 3/4" diameter hole through its center. The crystal was sealed in a dry atmosphere within an aluminum can with a glass window. The aluminum can had a reentrant "well" 5/8" diameter which extended into the hole in the crystal. The optical coupling between crystal and photomultiplier tube was optimized by means of a lucite disc and petroleum jelly. The thickness of the aluminum housing was 0.025".

5. Geiger-Mueller Tubes - Model TGC-2

This tube supplied by Tracerlab Inc. of Boston, Massachusetts,

was a mica end-window type with window thickness less than 2 mg/cm^2. The window diameter was 1.1". The tube was helium filled and organic vapor quenched.

6. Lead Shield-Vertical - Model LS-6

This shield was developed by the Atomic Energy Commission and is known as the "Schenectady" type. It was manufactured by Technical Associates, Burbank, California. It provided shielding of 1 3/8" of lead, and ¼" of brass and incorporated an aluminum liner to minimize back scattered radiation. The tube mount, was constructed of lucite and provided five sample positions. The overall geometric reproducability was estimated as 0.1%.

7. Lead Shield - Model 2254

This shield also furnished by Technical Associates of Burbank, California, was of similar construction but open on the bottom permitting fit over the sensitive portion of the vial counter shielding the top and sides. Shielding was 1" lead and 5/32" brass.

8. Organization of Equipment and Nomenclature

The Geiger-Mueller Counter assembly consists of TCG-2 Geiger-Mueller tube #2DL1 mounted in LS-6 lead shield, (serial #824) and operated in conjunction with the model 1070A scaling unit. The equipment was mounted on mobile racks as shown in Fig. 1. The 2250 scintillation counter (serial #124) shielded by model 2254 lead shield (serial #107) was alternately operated with this scaler.

The uncalibrated counter for interim counting, pending a-

vailability of the calibrated counter, hereafter referred to as the "interim counter", consisted of tube #2 DK95 mounted in lead shield, model LS-6, (serial #786) and was operated with a Berkeley Decade Scaler. The decade scaler was of common design with five microsecond resolving time and counting limit of 1,000 counts per second. It was adequate for the low counting rate where it was employed.

CHAPTER III

CALIBRATION OF THE GEIGER-MUELLER COUNTER

1. Discussion

The Geiger-Mueller Counter was calibrated by the determination of beta detection efficiency over an energy range of 0.155 to 2.32 Mev. Calibration was made at five different geometries giving a range of efficiencies for medium and high energy beta particles extending from about one to the order of 20 per cent.

The calibrated beta ray reference sources consist of five sources, protactinium - 234, bismuth - 210, thalium - 204, cobalt-60 and carbon - 14. Each source was evenly distributed over a copper planchet 22 mm in diameter. With the exception of the protactinium - 234 sources all active deposits were essentially weightless. The protactinium was in equilibrium with uranium - 238 of approximately 10 mg/cm^2 thickness. An aluminum foil covers the planchet to prevent loss of activity by mechanical abrasion and to filter out alpha and thorium - 234 radiations in the case of the protactium source. The planchet was mounted on an aluminum block and the whole assemblage held together by an aluminum retaining ring.

Appendix I(a) pertains to these reference sources and gives computed strengths at the date of calibration, April 15, 1955. They were furnished by the Atomic Instrument Company. The suppliers estimate of accuracy was ± 10 per cent. However, internal

consistancy of results and inter comparison with standards from a different supplier indicated that this estimate was too conservative. It seemed that an accuracy of $\pm$ 1 per cent was more realistic and this estimate was adopted in computations. Consequently it is believed that derived efficiencies are reliable to at least $\pm$ 10 per cent original estimate.

2. Laboratory Procedure

The counter was operated at a voltage of 1250 volts, approximately 100 volts above the lower limit of the plateau.

Tube dead time was determined with a Tektronix 511AD cathode ray oscilloscope. The value found was 100 $\pm$ 10 microseconds.

For each radioisotope used a mass absorption coefficient was determined from a plot of counting rate versus absorber thickness of aluminum. These data are listed in Appendix I(c) and presented graphically in Fig. 9. The data are shown normalized to 10 counts per second at zero adsorber thickness.

Each calibrated source was counted on each of the five shelves of the counter. Sufficient counts were taken to insure statiscal accuracy in the vicinity of $\pm$ 1% expressed as 95% confidence limits. These data are contained in Appendix I(b). If counting rates were as low as 5 counts per second, accuracy was insured by taking background counts as often as every three counting runs.

3. Mathematical Relations

The basic equation used in calculating beta counting efficiency is:

$M_o = E\ D\ f_d f_s f_b f_w$

The factors f_d, f_s, f_b and f_w are respectively corrections for dead time, self adsorption, back scattering and adsorption of window and air.

M_o = counting rate corrected for backgroun in counts per second

E = efficiency

D = disintegrations per second

$f_d = \frac{1-Mt}{M}$ where M is observed counting rate and t the dead time

f_s = 1 for all specimens used

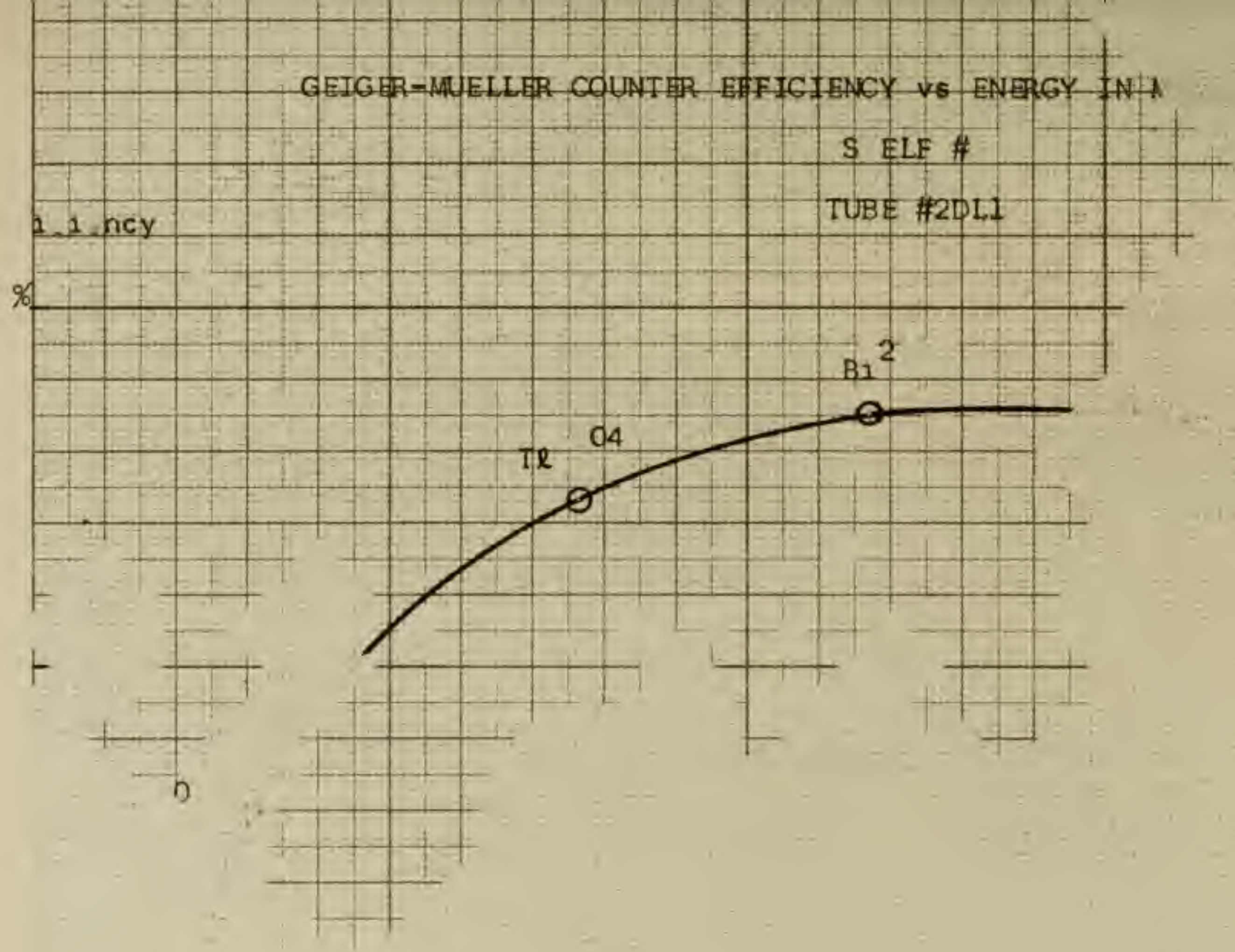
f_b = 1.61 for copper

$f_w = e^{\frac{-\mu}{\rho}x}$ where $\frac{\mu}{\rho}$ is the mass adsorption coefficient and x is thickness. For tube #2DL1, x = 1.9 + (air space)(1.2) $\frac{mg}{cm^2}$ (Appendix IId).

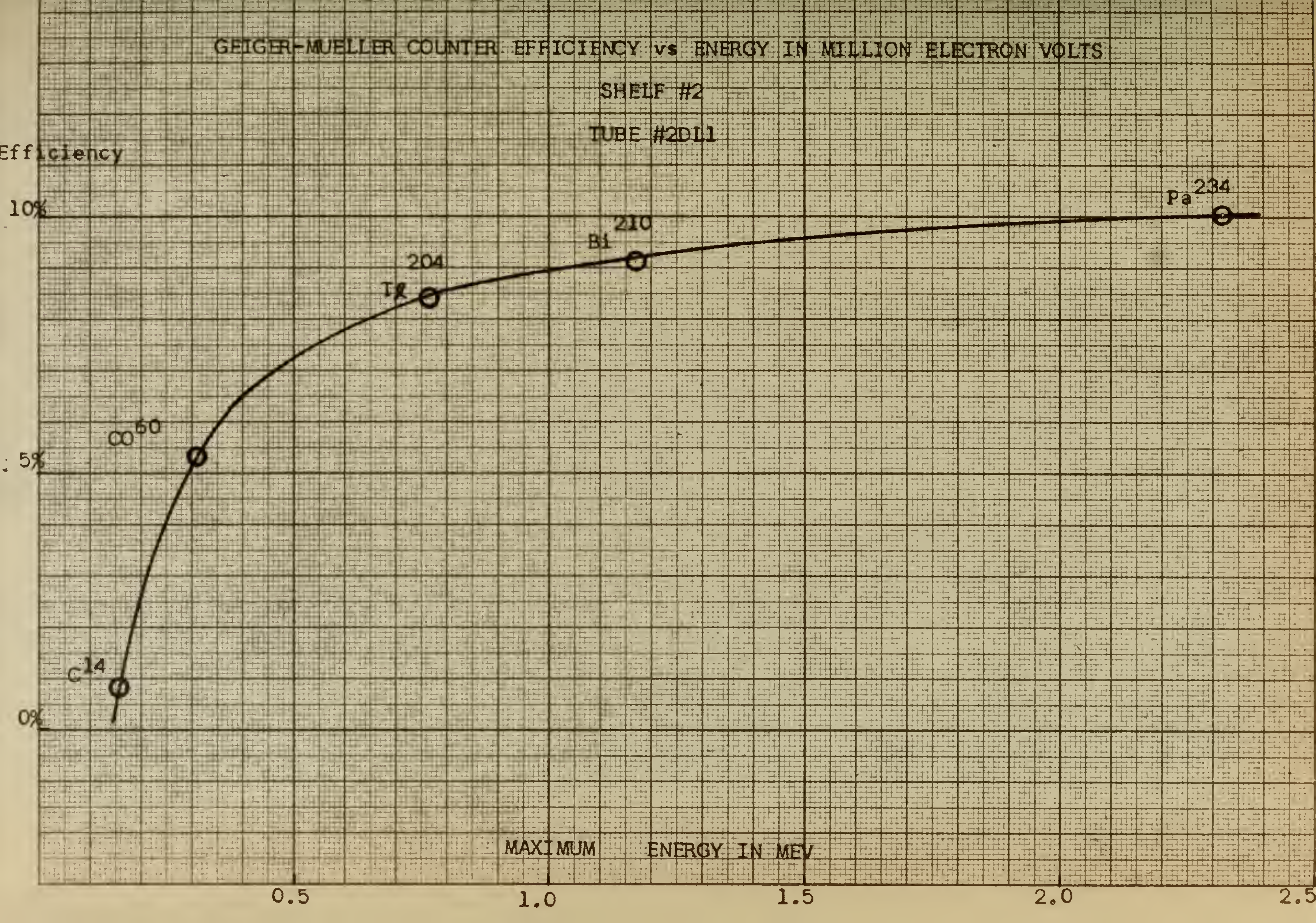
4. Graphical Representation

After the efficiency of each calibrated beta ray source was determined for each shelf (Appendix Ie) these data were plotted as beta counting efficiency versus maximum energy in Mev. (see Figs. 3 through 8). Counting efficiency for beta particles of any energy within the calibration range can be estimated by interpolation. The efficiencies increase regularly with energy and with decreasing separation between the tube and source for the lower four sample positions. On shelf #1 closest to the tube the

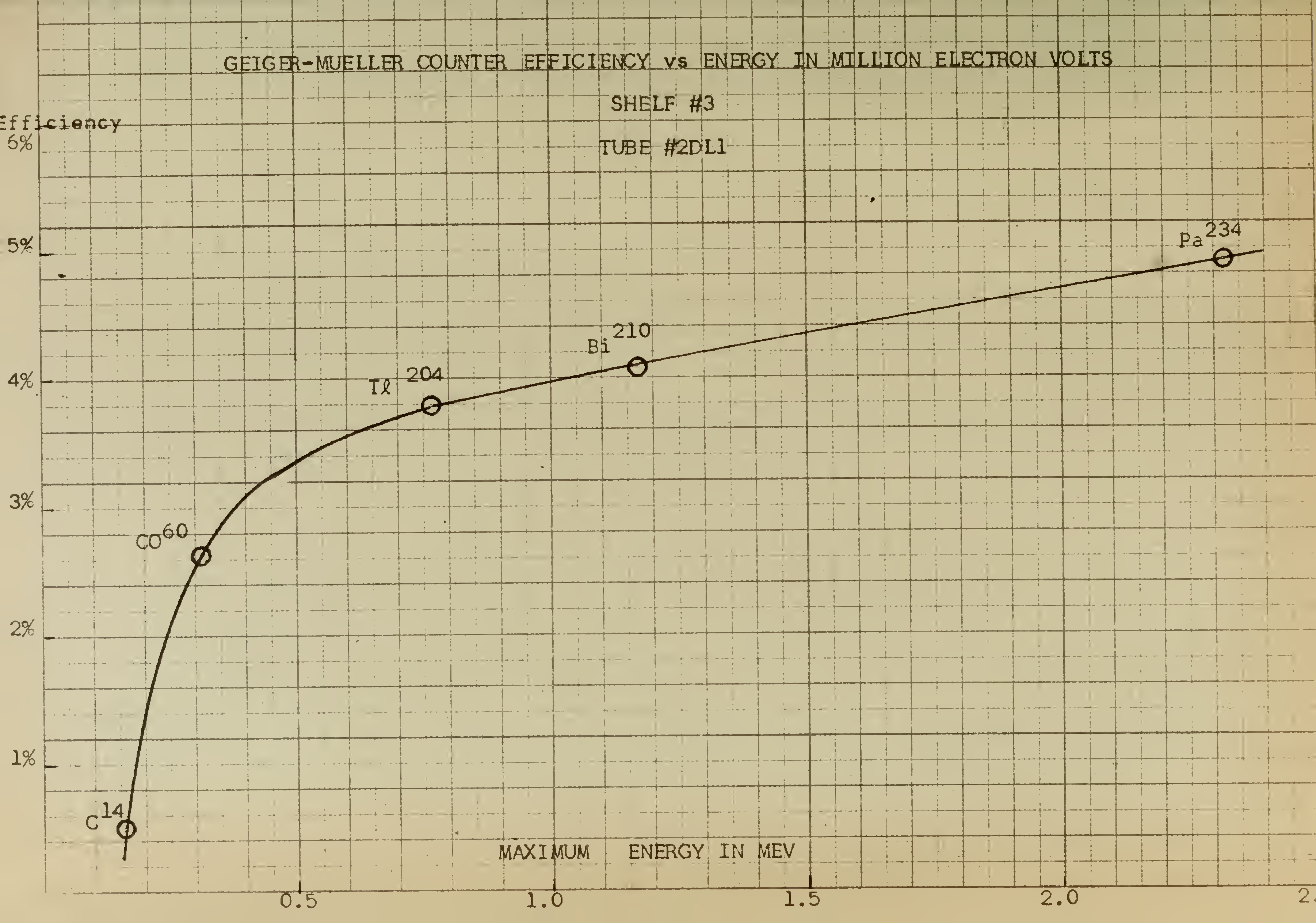
the efficiency curve shows a maximum in the vicinity of bismuth - 210, 1.17 Mev. maximum energy. This may be explained by particles of sufficiently high energy penetrating the tube wall outside the sensitive volume (at the extreme lower portion of the tube) and hence escaping detection.

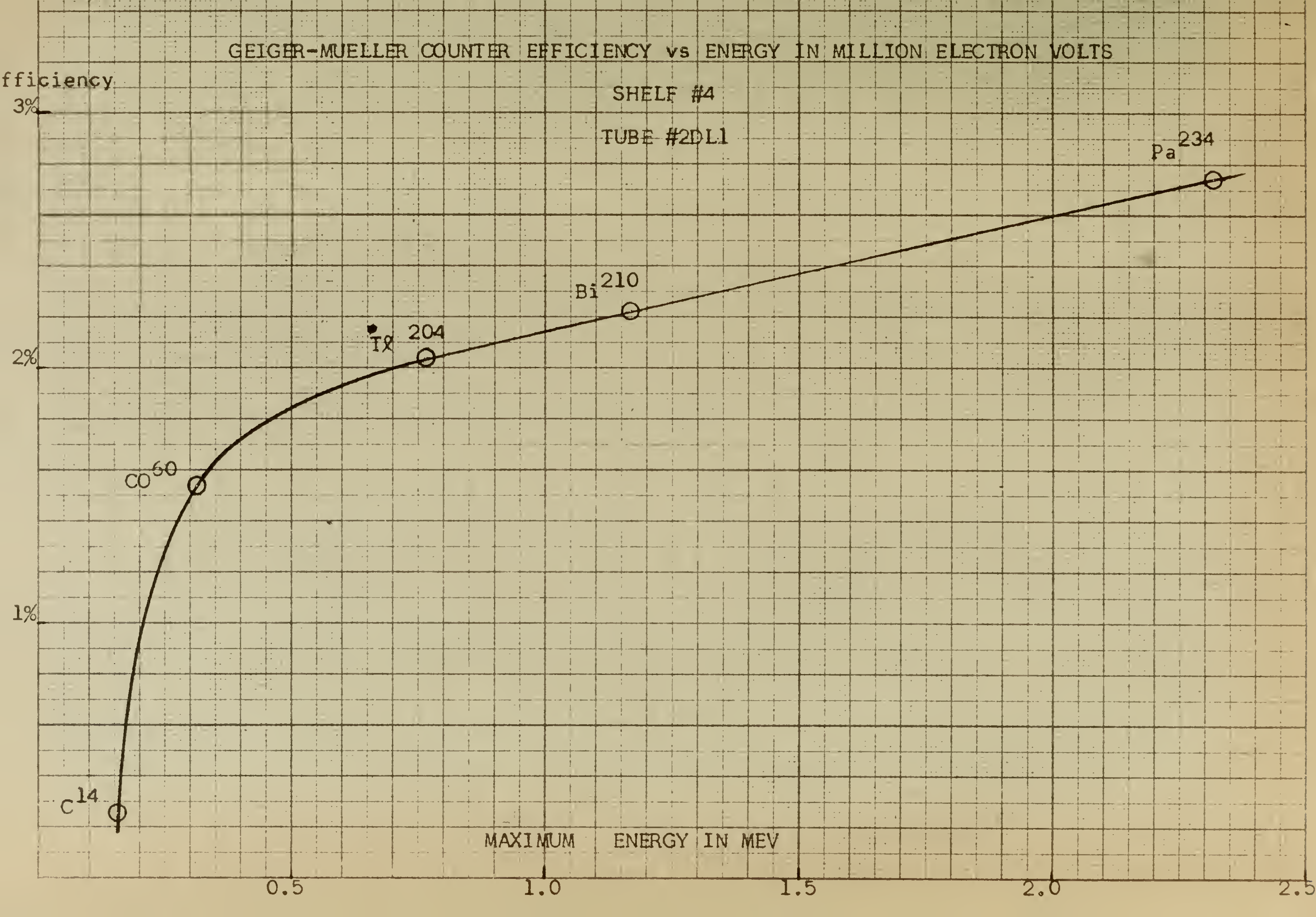


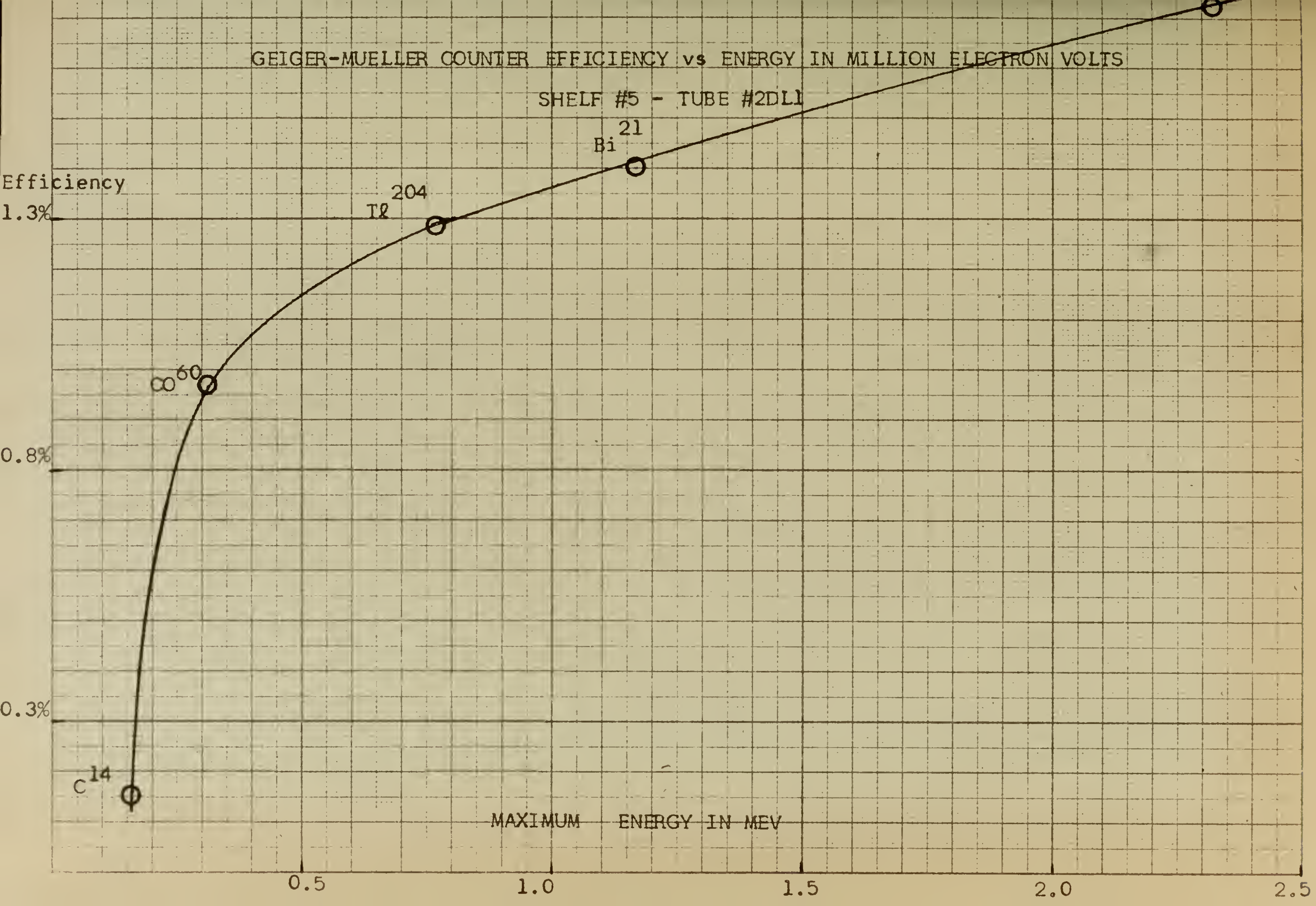
GEIGER-MUELLER COUNTER EFFICIENCY vs ENERGY IN
S ELF #
TUBE #2DL1
ncy
%
Tl
04
Bi
2



GEIGER-MUELLER COUNTER EFFICIENCY vs ENERGY IN MILLION ELECTRON VOLTS
SHELF #2
TUBE #2D11
Efficiency
10%
5%
0%
Pa234
Bi210
Tl204
Co60
C14
MAXIMUM ENERGY IN MEV
0.5
1.0
1.5
2.0
2.5


GEIGER-MUELLER COUNTER EFFICIENCY vs ENERGY IN MILLION ELECTRON VOLTS
SHELF #3
TUBE #2DL1
Efficiency
6%
5%
4%
3%
2%
1%
Pa 234
Bi 210
Tl 204
CO 60
C 14
MAXIMUM ENERGY IN MEV
0.5
1.0
1.5
2.0


GEIGER-MUELLER COUNTER EFFICIENCY vs ENERGY IN MILLION ELECTRON VOLTS
SHELF #4
TUBE #2DL1
fficiency
3%
2%
1%
C14
CO60
Tl 204
Bi210
Pa234
MAXIMUM ENERGY IN MEV
0.5
1.0
1.5
2.0
2.5


GEIGER-MUELLER COUNTER EFFICIENCY vs ENERGY IN MILLION ELECTRON VOLTS
SHELF #5 - TUBE #2DL1
Bi 21
Tl 204
CO 60
C 14
Efficiency
1.3%
0.8%
0.3%
MAXIMUM ENERGY IN MEV
0.5
1.0
1.5
2.0
2.5

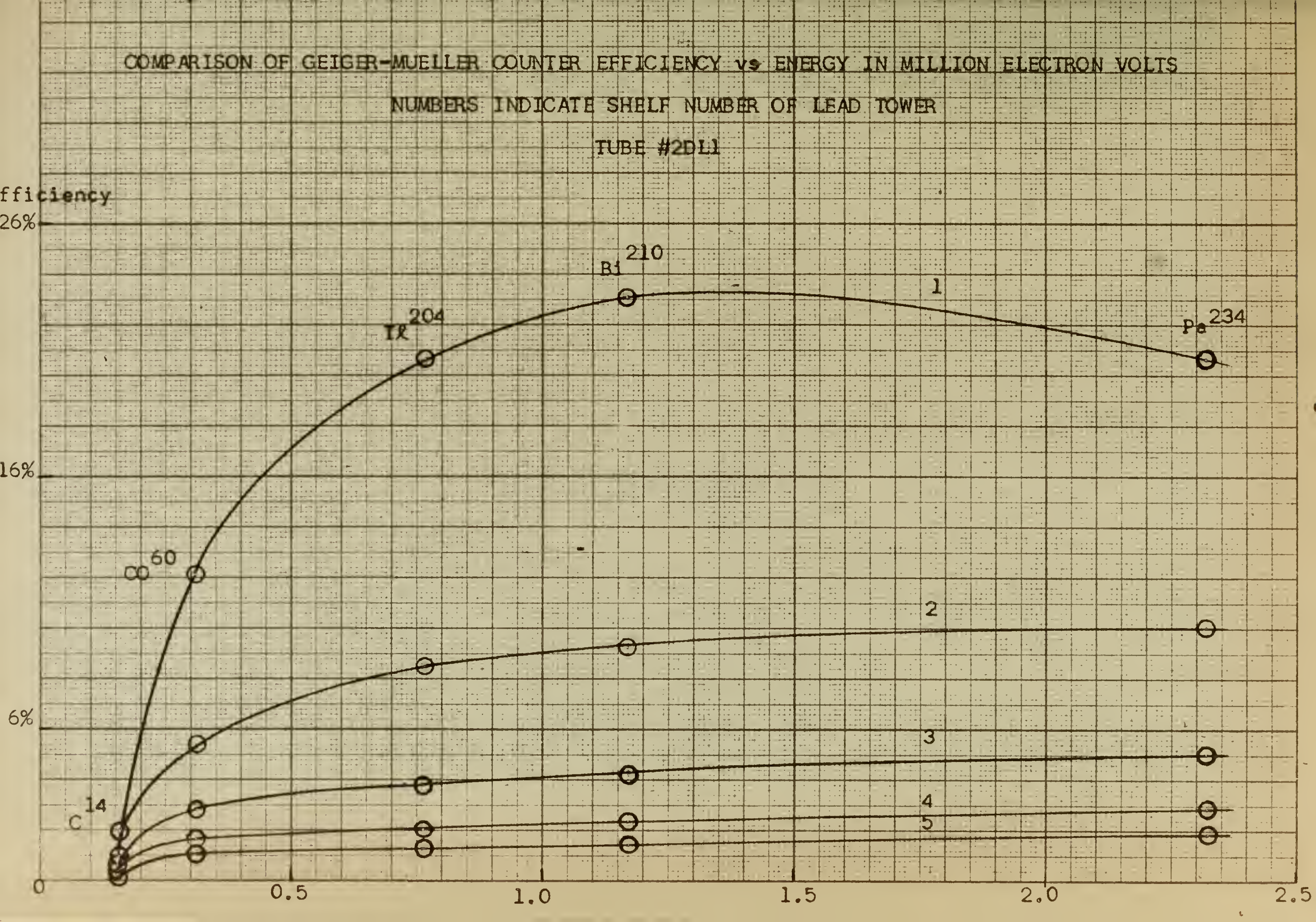
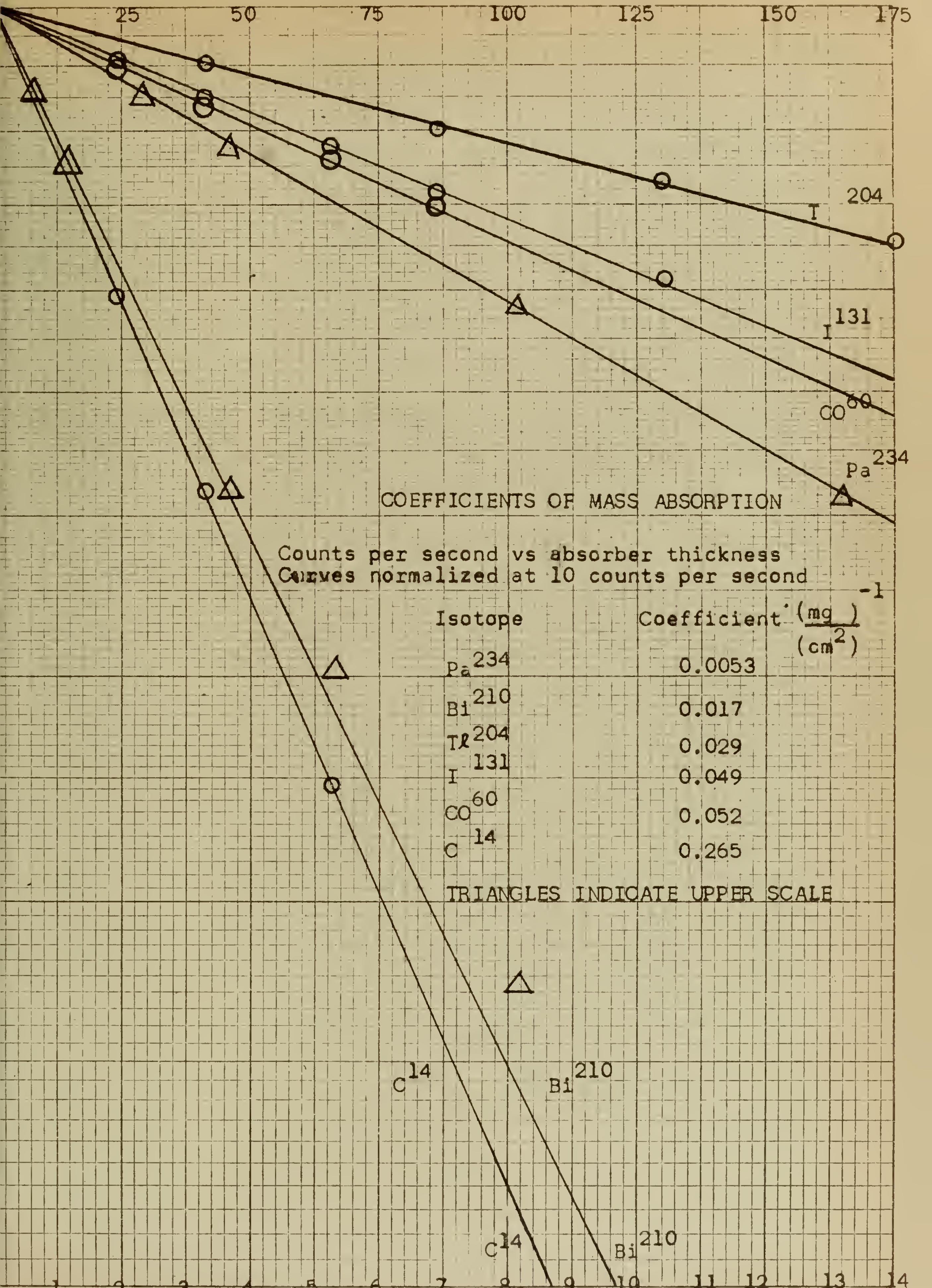

COMPARISON OF GEIGER-MUELLER COUNTER EFFICIENCY vs ENERGY IN MILLION ELECTRON VOLTS
NUMBERS INDICATE SHELF NUMBER OF LEAD TOWER
TUBE #2DL1
fficiency
26%
16%
6%
0
0.5
1.0
1.5
2.0
2.5
C 14
Co 60
Tl 204
Bi 210
Pa 234
1
2
3
4
5

FIGURE 9



25 50 75 100 125 150 175
Tℓ 204
I 131
CO 60
Pa 234
COEFFICIENTS OF MASS ABSORPTION
Counts per second vs absorber thickness
Curves normalized at 10 counts per second
Isotope
Coefficient (mg/cm²)⁻¹
Pa 234 0.0053
Bi 210 0.017
Tℓ 204 0.029
I 131 0.049
CO 60 0.052
C 14 0.265
TRIANGLES INDICATE UPPER SCALE
C 14
Bi 210
1 2 3 4 5 6 7 8 9 10 11 12 13 14

CHAPTER IV

CALIBRATION OF THE VIAL SCINTILLATION DETECTOR FOR I^{131}

1. Discussion

The advantage of the scintillation detector is that all gamma quanta absorbed in the volume of the crystal can be counted and that even very low energy gamma rays may be counted. However, to insure proper gamma ray counting, beta rays emitted by an isotope should be completely absorbed before they reach the crystal. In the present scintillator counter the thickness of the aluminum crystal housing plus the glass vial is approximately 400 $\frac{mg}{cm^2}$ hence beta emissions from I^{131} are completely adsorbed. Extraneous radiations are reduced by a lead shield surrounding the detector.

2. Laboratory Procedure

The optimum counting rate for I^{131} as a function of voltage was determined and an operating point of 1225 volts selected.

A solution of iodine - 131 in distilled water was prepared. From this solution, four copper backed I^{131} planchets were made using the following volumes for beta ray counting:

Planchet #	Millileters of I^{131}
1	0.852
2	0.846
3	0.872
4	0.859

These were counted on the fifth shelf of the Geiger-Mueller counter

(tube#2DKL95) and at a later date a compairson in counting rate between this counter and the calibrated counter was made. (Appendix III). From the same solution twelve vials, each containing 1 ml of solution, were prepared for gamma counting by the scintillation counter. (Appendix II).

3. Determination of I^{131} Strength

All counts have been decayed back to 1000 hours February 9, 1955 and corrected to 1 milliliter.

Counting rate of interim counter for I^{131} was 89.7 ± 0.45% counts per second per milliliter. (Appendix IIIa).

Ratio of counting rates of calibrated counter to interim counter for I^{131} was 1.123 ± 0.69%. (Appendix IIIb).

From Fig. 7, the beta counting efficiency for I^{131} was estimated as follows:

Beta energy in MEV	(% abundance)(Beta counting efficiency)
0.81;	0.007 x 0.0130 = 0.00009
0.61;	0.872 x 0.0121 = 0.01055
0.34;	0.093 x 0.010 = 0.00093
0.25;	0.028 x 0.0081 = 0.00023
Total efficiency	0.01180±2.5%*

$$D = \frac{M}{f_s f_w f_b E} = \frac{1.123 \times 89.7}{1 \times 0.621 \times 1.61 \times 0.0118}$$

D = 8,536 ± 2.6% disintegrations per second per milliliter

*Estimated maximum interpolation error

4. Determination of Scintillation Counter Efficiency

The efficiency of the scintillation counter is given by:

$$E_s = \frac{M_s}{D}$$

where: M_s = scintillator counting rate less background count

D = strength of the isotope in disintegrations per second

Other factors which must be considered for the Geiger-Mueller counter are insignificant in this calibration. The scintillator counting rate for I^{131} decayed back to 1000 hours February 9, 1955, is 4,289 ± 0.54% counts/second/ml, (Appendix II)

$$E_s = \frac{M_s}{D} = \frac{4,289 \pm 0.54\%}{8,536 \pm 2.6\%}$$

$$E_s = 0.502 \pm 2.7\% \text{ for 1 ml of } I^{131}$$

CHAPTER V

RESULTS AND CONCLUSIONS

Counter efficiency for five geometries of a Geiger-Mueller Counter has been determined by the calibrated detector method, offering an estimated accuracy of ± 2.5% for beta particles between 0.155 and 2.32 MEV.

A procedure for inter calibration of a Vial Scintillation Counter and a Geiger-Mueller Counter has been presented and the scintillation counter calibrated for I^{131}. Efficiency for I^{131} was determined as 0.502 ± 2.7% for optimum experimental conditions.

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APPENDIX I

Calibration data for Geiger-Mueller Counter

Components:

Tube #2DL1, Lead Shield #824, Multiscaler #4522

Operational Data:

Scaler voltage setting 1250 Volts, Pulse Height Selector + 20 volts

Tube Data:

Dead time 10^{-4} seconds

Window thickness 1.9 $\frac{mg}{cm^2}$

Counts:

All counts corrected for dead time and background count; accuracy expressed as 95% confidence limit.

a) CALIBRATED BETA RAY REFERENCE SOURCES

Isotope	C^{14}	Co^{60}	Tl^{204}	Bi^{210}	Pa^{234}
$T_{1/2}$	0.57×10^{4} yrs	5.3 yrs	4.0 yrs	22 yrs	4.5×10^{9} yrs
Beta Energy	0.155 MEV	0.31 MEV	0.765 MEV	1.17 MEV	2.32 MEV
Calibrated Source Strength 10-51	14.6×10^{-5} Mc	1.03×10^{-5} Mc	1.03×10^{-5} Mc	1.31×10^{-5} Mc	0.57×10^{-5} Mc
Computed Strength 4-15-55	14.6×10^{-5} Mc	6.49×10^{-6} Mc	5.57×10^{-6} Mc	1.17×10^{-6} Mc	0.57×10^{-5} Mc
Disintegrations Per Second 4-15-55	5,400	240	205	434	211

b) COUNTING RATES OF REFERENCE SOURCES FOR CALIBRATION

SHELF NUMBER	1	1	1	1	1
C.P.S.	91.8 ± 0.32%	42.0 ± 0.31%	64.2 ± 0.37%	155.5 ± 0.23%	69.7 ± 0.57%
Date	3-28-55	3-28-55	3-25-55	3-25-55-	3-23-55
Number of Data Averaged	10	10	10	10	10
Total Counts/run	38,000	17,000	26,000	64,000	30,000
SHELF NUMBER	2	2	2	2	2
C.P.S.	26.1 ± 0.38%	16.8 ± 0.64%	24.9 ± 0.42%	59.7 ± 0.20%	33.[illegible] ± 0.46%
Date	3-30-55	3-30-55	3-29-55	3-29-55	3-29-55
Number of Data Averaged	10	10	10	10	10
Total Counts/run	10,000	10,000	10,000	25,000	14,000
SHELF NUMBER	3	3	3	3	3
C.P.S.	7.51 ± 0.77%	7.45 ± 0.59%	10.52 ± 0.45%	25.8 ± 0.59%	16.1 ± 0.67%
Date	4-4-55	4-4-55	4-1-55	4-1-55	3-31-55
Number of Data Averaged	10	10	10	10	10
Total Counts/run	10,000	10,000	10,000	10,000	10,000
SHELF NUMBER	4	4	4	4	4
C.P.S.	2.64 ± 0.96%	3.80 ± 1.09%	5.35 ± 0.80%	13.55 ± 0.48%	8.91 ± 0.69%
Date	4-23-55	4-23-55	4-22-55	4-21-55	4-5-55
Number of Data Averaged	20	16	15	12	15
Total Counts/run	2,500	2,500	2,500	10,000	5,000
SHELF NUMBER	5	5	5	5	5
C.P.S.	1.06 ± 2.70%	2.[illegible]6 ± 0.77%	3.21 ± 0.91%	6.25 ± 0.83%	5.55 ± 1.06%
Date	4-20-55	4-18-55	4-18-55	4-16-55	4-15-55
Number of Data Averaged	18	1[illegible]	13	17	20
Total Counts/run	1,200	2,500	2,500	5,000	2,500

c) DATA FOR DETERMINATION OF MASS ABSORBER COEFFICIENTS

Absorber Thickness Expressed in Milligrams per$(cm)^2$

	C^{14}	Co^{60}	I^{131}	Tl^{204}	Bi^{210}	Pa^{234}
Absorber:	0	0	0	0	0	0
Counts:	7.60	7.46	246.0	10.7	25.8	16.4
Absorber:	1.93	1.93	1.93	3.28	6.89	6.89
Counts:	4.51	6.65	220.0	9.62	21.9	15.7
Absorber:	3.28	3.28	3.28	6.89	14.10	28.80
Counts:	3.18	[illegible].25	205.0	8.52	1[illegible].9	13.9
Absorber:	5.22	5.22	5.22	10.40	28.80	46.10
Counts:	1.88	5.[illegible]	190.0	7.83	14.7	12.7
Absorber:		6.89	6.89	14.10	46.10	102.00
Counts:		5.21	176.0	7.06	10.8	9.5
Absorber:			10.4	19.30	66.50	165.00
Counts:			155.0	6.24	7.86	6.85
Absorber:					102.00	
Counts:					4.47	

d) DETERMINATION OF ALUMINUM WINDOW AND AIR ABSORPTION FACTOR f_w

(Air density = 1.20 $\frac{mg}{cm^2}$ at 20°C ± 2° and 760 mm)

SHELF #	1	2	3	4	5
Air distance from tube window to shelf	0.25 cm	1.7 cm	3.3 cm	5.0 cm	6.5 cm
$x = 1.9 + (\text{air space}) \times 1.20 \frac{mg}{cm^2}$	2.20	3.94	5.86	7.90	9.70
$f_w = e^{-\frac{\mu}{\rho} x}$					
f_w for C^{14}	0.540	0.352	0.212	0.123	0.0765
f_w for Co^{60}	0.901	0.814	0.737	0.633	0.604
f_w for I^{131}	0.896	0.824	0.750	0.679	0.621
f_w for Tl^{204}	0.938	0.893	0.843	0.795	0.755
f_w for Bi^{210}	0.963	0.935	0.905	0.874	0.848
f_w for Pa^{234}	0.988	0.979	0.969	0.959	0.949

e) COMPUTED COUNTING EFFICIENCY FOR CALIBRATED BETA RAY SOURCES AS OF 4-15-55

SHELF	C^{14}	Co^{60}	Tl^{204}	Bi^{210}	Pa^{234}
1	0.0196 ± 1.06%	0.1206 ± 1.06%	0.2074 ± 1.07%	0.2310 ± 1.03%	0.2077 ± 1.0[illegible]
2	0.00853 ± 1.07%	0.0534 ± 1.17%	0.0845 ± 1.08%	0.0914 ± 1.03%	0.0998 ± 1.1[illegible]
3	0.00407 ± 1.26%	0.0262 ± 1.16%	0.0378 ± 1.09%	0.0408 ± 1.21%	0.0489 ± 1.[illegible]
4	0.00247 ± 1.41%	0.0155 ± 1.49%	0.0204 ± 1.28%	0.0222 ± 1.11%	0.0[illegible]74 ± 1.[illegible]
5	0.00159 ± [illegible].68%	0.00968 ± 1.[illegible]5%	0.0129 ± 1.29%	0.0139 ± 1.29%	0.017[illegible] ± 1.4[illegible]

APPENDIX II

Calibration data for Vial Scintillation Detector

Components:

Vial Scintillation Detector #124

Multiscaler #4522

Operational Data:

Scaler voltage setting 1225 volts

Pulse height selector - 0 volts

Counts:

All counts for Vial Scintillation Detector corrected for background only

4,000,000 counts/run for vials 1 through 6

300,000 counts/run for vials 7 through 12

Average value includes 95% confidence limit

Isotope:

I^{131} - 1 ml per vial

COUNTING RATE OF VIAL SCINTILLATION DETECTOR

Sample Vial #	Hour and Date	C.P.S. Corrected for Background	C.P.S. Corrected to 1000 hrs	C.P.S. Averaged 2-9-55
1	2-9-55		2-9-55	
	0950	4,212.6	4,212.6	
	1010	4,204.7	4,204.7	
	1030	4,198.7	4,203.7	4,207
2	1050	4,230.9	4,244.1	
	1110	4,236.4	4,254.4	
	1127	4,242.8	4,268.8	4,255
3	1145	4,391.3	4,419.0	
	1205	4,391.0	4,423.1	
	1220	4,391.5	4,427.4	4,423
4	1240	4,378.6	4,404.8	
	1345	4,312.0	4,377.5	
	1450	4,299.6	4,377.6	4,386
5	2-10-55			
	0850	4,035.7	4,377.2	
	0910	4,011.6	4,360.2	
	0930	4,008.6	4,361.1	4,366
6	0940	3,963.0	4,323.1	
	1000	3,971.7	4,341.8	
	1030	3,972.6	4,350.6	4,338
7	2-21-55			
	0830	1,509.1	4,239.2	
	0846	1,489.3	4,183.5	
	0854	1,502.3	4,220.1	4,214
8	0857	1,517.1	4,261.5	
	0904	1,524.6	4,281.0	
	0907	1,520.2	4,282.2	4,274
9	0916	1,505.8	4,265.8	
	0925	1,490.1	4,221.5	
	0930	1,502.5	4,256.4	4,247
10	0935	1,494.9	4,234.8	
	0940	1,492.0	4,222.8	
	0945	1,498.2	4,244.4	4,234
11	0950	1,501.9	4,250.4	
	0954	1,502.8	4,257.7	
	1000	1,497.1	4,241.3	4,249
12	1005	1,509.0	4,274.8	
	1010	1,509.8	4,277.3	
	1015	1,508.4	4,273.3	4,275

Average Value
4,289 ± 0.54%

APPENDIX III

Data for determination of I^{131} strength

I^{131} planchets were counted with an interim Geiger-Mueller tube #2DK95, and at a later date a relative counting rate was determined between this tube and the calibrated counter tube.

Components:

Tube #2DK95

operated at 1350 volts

dead time 1.1 x 10^{14} seconds

Tube #2DL1 - see Appendix II

Counts:

All counts taken on 5th shelf and corrected for dead time and background.

Averaged values include 95% confidence limits.

a) COUNTING RATES FOR I^{131} PLANCHETS

Planchet Number	Date & Hour 2-14-55	Counts/run	C.P.S. corrected for dead time & BC	Correction factor to 1 ML	Correction Factor to 1000 hrs 2-9-55	Corrected c unts as of 1000 hrs 2-9-55
1		10,000	48.1341	1/0.852	1/0.640	88.2741
			49.5575			90.8844
	1351		48.3786			88.7224
			49.3004			90.4129
			48.5163			88.9750
2		10,000	49.1484	1/0.846	1/0.639	89.0224
			44.1584			89.0405
	1438		49.2858			89.2713
			48.5737			87.9814
			49.5475			84.7453
3		10,000	49.8678	1/0.872	1/0.636	89.9183
			50.0997			90.3364
	1538		50.6693			91.3635
			49.9499			90.0663
			49.9095			89.9993
4		10,000	49.4928	1/0.859	1/0.634	90.8791
			48.6693			89.3670
	1630		48.5260			89.1030
			49.2202			90.3786
			48.8135			89.6318

Average Value 89.7 ± 0.45%

b) REALTIVE COUNTING RATE FOR TUBES #2DL1 and #2DK95 FOR I^{131}

Tube #	4-19-55 Hour	Counts/run	C.P.S. corrected for deadtime and BC	Average Value
2 DK95	1420	40,000	66.690174	
	1445		67.169176	
	1513		66.853023	
	1535		66.673986	
	1600		66.167871	66.71 ± 0.53%
2 DL1	1430	40,000	75.45797	
	1500		75.26645	
	1521		73.97837	
	1545		75.46167	
	1612		74.38248	74.91 ± 0.063%

$$\frac{\text{Counting rate tube \#2 DL 1}}{\text{Counting rate tube \#2 DK 95}} = 1.123 \pm 0.69\%$$

Thesis
M8225
28465
Morey
Inter calibration between a vial scintillation detector and a Geiger-Mueller counter.